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Floristic Study of the Herbaceous Vegetation of Wet Lowlands in Aru Territory, Ituri Province (Democratic Republic of Congo)

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ABSTRACT

The study of plant communities was conducted using the Braun-Blanquet phytosociological method, supported by physiognomic, chorological, and numerical approaches. This phytosociological investigation aimed to inventory the biological diversity of wet lowlands in the eastern part of the Aru River watershed and to establish the ecological diagnostics of the surveyed herbaceous vegetation units. The wet lowlands studied constitute part of the water supply feeding the Aru River, one of the numerous tributaries of the Congo Basin in northeastern Democratic Republic of Congo (DRC). These lowlands show limited ecological niche and species diversity due to permanent soil moisture and various anthropogenic activities.

A total of 122 species, belonging to 83 genera, 37 families, and 23 orders, were recorded. These species fall into three cladistic categories: Eudicotyledons (77 species; 63.1%), Monocotyledons (44 species; 36.0%), and Pteridophytes (1 species; 0.8%). As in most savannah regions, pteridophytes are very rare throughout Aru Territory.

The floristic inventory was carried out in 10 phytocoenoses, including communities dominated by: *Cyperus distans* L.F. var. *distans*, *Hyparrhenia subplumosa*, *Polygonum pulchrum* Blume, *Leersia hexandra* Sw., *Triumfetta cordifolia* A. Rich var. *cordifolia*, *Vossia cuspidata* (Roxb.) Griff., *Pennisetum purpureum* K. Schum., *Cyperus papyrus* L. subsp. *percamentus*, and *Ludwigia abyssinica* A. Rich.

The Poaceae family is the most diverse (24 species), although the physiognomy of the vegetation is shaped mainly by Cyperaceae, dominated by *Cyperus distans* var. *distans*. The environment is favorable to geophytes and hemicryptophytes.

Anemochory is the predominant dispersal mode, with sclerochorous and sporochores being frequent. The phytogeographical spectrum is dominated by species with very wide distributions, with pantropical species being the most represented.

A perennial species of Melastomataceae, *Centradenia inaequilateralis* (Schltdl. & Cham.), was collected in the humid station as an indigenous species. Originally from Mexico, it is now introduced in tropical and subtropical regions, including Réunion Island, where it is cultivated in botanical gardens.

Floristic homogeneity was observed between some groupings, with a Sorensen coefficient of 60%, particularly between the mixed grouping (*Triumfetta cordifolia* var. *cordifolia* + *Cyperus distans* var. *distans*) and the *Pennisetum purpureum* community. Some phytocoenoses exhibited very low species diversity indexes and shared no species in common.

Keywords: flora, vegetation, humidity, phytosociology

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INTRODUCTION

The Territory of Aru lies within a savanna zone characterized by heterogeneous vegetation. It consists of grass savanna in the southeast, wooded savanna in the southwest, shrub savanna in the central part, a semblance of steppe in the northeastern part, and a relief composed of mountains, hills, plateaus, and valleys crossed by watercourses of relative importance, the largest being the Aru River.

Vegetation is a component of the natural ecosystem whose scientific understanding is of great importance for the management and conservation of biodiversity. It shelters fauna, determines life conditions, influences precipitation, and largely shapes human life. Misuse of vegetation and flora by humans often alters its structure, disrupts animal life, changes the local climate, and deprives people of natural resources (MURAY, 2009).

The transfer of most upland crops into humid lowlands by cultivators is one of the main causes of the progressive loss of soil fertility in wetland areas of the Aru Territory. During the rainy season, this loss is compensated by mineral elements carried by runoff waters from the plateaus, allowing the colonization of wet lowlands by adapted plant species analyzed in this study.

Floristic inventories and studies of plant communities initiated during the colonial era have not yet covered the entire Democratic Republic of Congo.

The existence of the National Institute for Agronomic Research (I.N.E.R.A.) in the Democratic Republic of Congo (DRC) has enabled scientists to conduct various studies on herbaceous vegetation formations, mainly in the central basin. In wetlands, the works of Lebrun on the Papyrion (1947), Mullenders on *Andropogonium schinensis* (1949), and Léonard on *Echinochloion tropicale* (1950) are notable examples, including ecological research in wetlands by scholars of the Faculty of Sciences of the University of Kisangani. However, botanical knowledge of the northeastern region of the country remains very limited.

Taton (1940) reports several studies conducted in the central part of Ituri Province, in the Nioka region, such as the association of *Galinsoga parviflora* CAV. And *Solanum nigrum*. The extreme northern part of Ituri, which is the focus of the present phytosociological study, has never undergone a floristic inventory.

The continuation of floristic inventories and ecological analyses of interacting systems (vegetation, soil, water, etc.) constitutes the purpose of our commitment to improving botanical knowledge of herbaceous plants often threatened by human activities and colonizing the humid valleys within the watershed of the Aru River.

MATERIALS AND METHODS

Description of the Study Area

Aru is one of the five Territories forming Ituri Province, located in central Africa and in the northeastern part of the Democratic Republic of Congo. This administrative entity occupies the extreme north of the Province.

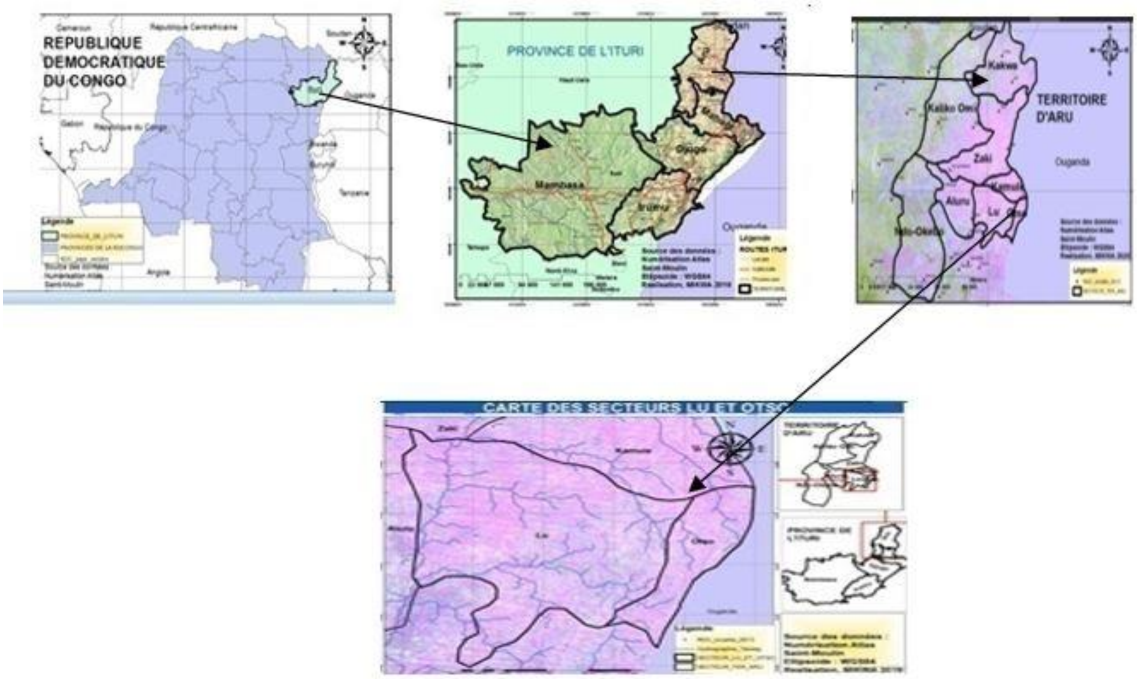


Figure 1: Maps of Congo, Ituri Province, Aru Territory, and the chiefdoms of Lu and Otso

Note: The Territory of Aru is located between 2°26' and 3°29' North latitude and East longitude (Idring'i and Bamuhiga, 1988).

Its boundaries define it within a natural region:

- To the east, it borders Uganda, separated by the watershed between the Nile and the Congo;
- To the north, South Sudan;
- To the northwest, Faradje Territory;
- To the southwest, Watsa Territory;
- To the south, Mahagi Territory.

At the limit with Watsa Territory, the savannah becomes grassy, resembling that resulting from the degradation of the Guinean Forest Province, where the valleys evoke forest galleries. The north-western and south-western boundaries outline a line that constitutes a real botanical separation. Crossing this line toward Watsa in Haut-Uélé Province reveals the limit of the high plateaus and the end of the large livestock breeding zone.

Köppen's classification best suits the climatic characteristics of the study area. In this system, the region experiences a tropical savanna climate (Aw), modified throughout the year by different winds, including a dry trade wind blowing during the dry seasons, which may itself be influenced by local microclimates due to nearby mountains and marshes. Measurements taken at the I.N.E.R.A. Mont-Hawa station reveal an average altitude of 1,350 m and an annual mean precipitation of 1,501.5 mm (Lubini, 1988).

Data Collection

Phytosociological surveys were conducted in plant communities dominated by Cyperaceae. Figure 2 shows *Cyperus distans var. distans* in the foreground and *Cyperus papyrus percamentus* in the background.

Figure 2: *Cyperus distans var. distans* and *Cyperus papyrus percamentus*

Several tools were used for field data collection: a knife to sample papyrus stems and cut them to herbarium-press size; a metal tape to measure survey plots; a pH meter to assess the hydrogen potential of marsh soils; and a wooden herbarium press to dry and preserve botanical specimens.

To ensure a scientifically valid assessment, phytosociological surveys were carried out on the most homogeneous surfaces possible, following the Braun-Blanquet–Tüxen method. Observations and investigations were conducted during both dry and rainy seasons.

The scientific name *Cyperus papyrus percamentus* was determined by comparison with the morphology of *Cyperus papyrus var. zaïriensis*, also considering the proximity of the study region to the Nile Valley its region of origin as indicated by sources such as jardinage.lemonde.fr, jardinsupicvert.com, and Wikipedia. Companion species names were verified at the Herbarium of the Faculty of Sciences, University of Kisangani.

Data Analysis

Floristic diversity among families was assessed considering the 15 families with two or more species recorded. The pie chart is presented according to three clades. Bar charts were used to analyze life forms following Raunkiaer's classification (1934), improved by Lebrun (1947) and other authors; diaspore types defined by Dansereau and Lehms (in Lebrun 1960); and phytogeographical categories derived from subdivisions proposed by White (1979, 1986).

Floristic affinity among phytocoenoses was evaluated using Sørensen similarity coefficients, expressing the degree of resemblance in terms of species shared between surveys. The software PAST was used to compare communities based on their respective diversity indices.

RESULTS

Ecological Condition

The marshy soil remains hydromorphic throughout the year, even during periods of drought. Hemicryptophytes dominate other biological types. Asteraceae and Malvaceae formations are frequent. The vegetation is heliophilous and grows on soil with a pH generally below 7.

Floristic Analysis

Recorded flora

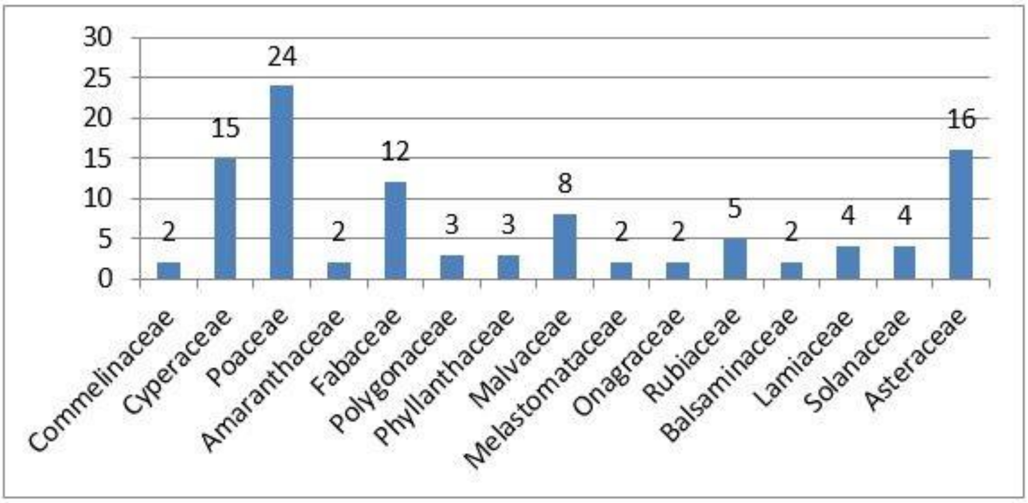
The various surveys produced a global matrix of 122 species belonging to 83 genera, 37 families, and 23 orders. Among them, the perennial plant *Centradenia inaequilateralis* (Melastomataceae) was found in the studied humid station, sparsely associated with *Cyperus distans var. distans* in small groups of two or three individuals. This species originates from Mexico and is now introduced in tropical and subtropical regions up to Réunion Island. It has not yet been recorded in the flora of the Tshopo Subregion in the Congolese central basin.

Figure 3: ***Centradenia inaequilateralis***

Specific diversity of the main families

(Figure preserved)

The Poaceae family is the most diversified, with 24 species, followed by Asteraceae (16 species), Cyperaceae (15 species), and Fabaceae (12 species).



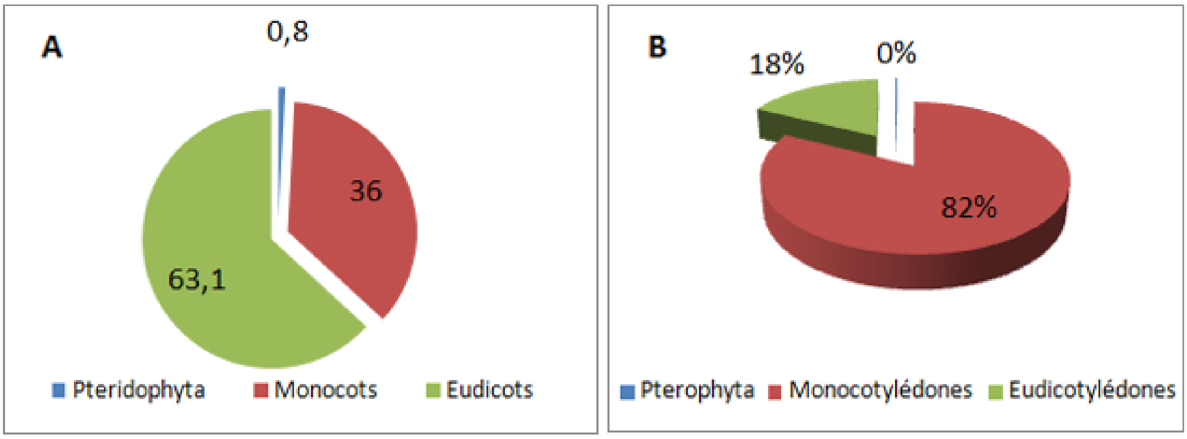


Figure 4: Specific diversity of the 15 families

Other families are poorly represented. Human activities favor Poaceae over the typically helophytic Cyperaceae. Drainage for agriculture promotes the invasion of wet lowlands by dryland species.

Among Poaceae, *Hyparrhenia subplumosa* has not been mentioned in botanical studies conducted in the central basin of the DRC. However, since several *Hyparrhenia* species are endemic to the Sudano-Zambezian region, *H. subplumosa* is described here. The community belongs to the alliance Themedion triandrae (Lebrun 1947) of eastern grass savannas, within the order *Themedietalia triandrae*, sometimes classified under Hyparrhenietea.

Cladistic categories

Of the 122 recorded species, 77 (63.1%) are eudicots, dominating the 44 monocots (36%) and the single pteridophyte species (0.8%). Wet lowland habitats are not favorable to pteridophytes.

Monocots (82%) are denser than Eudicots (18%) and Pteridophyta (0.9%).

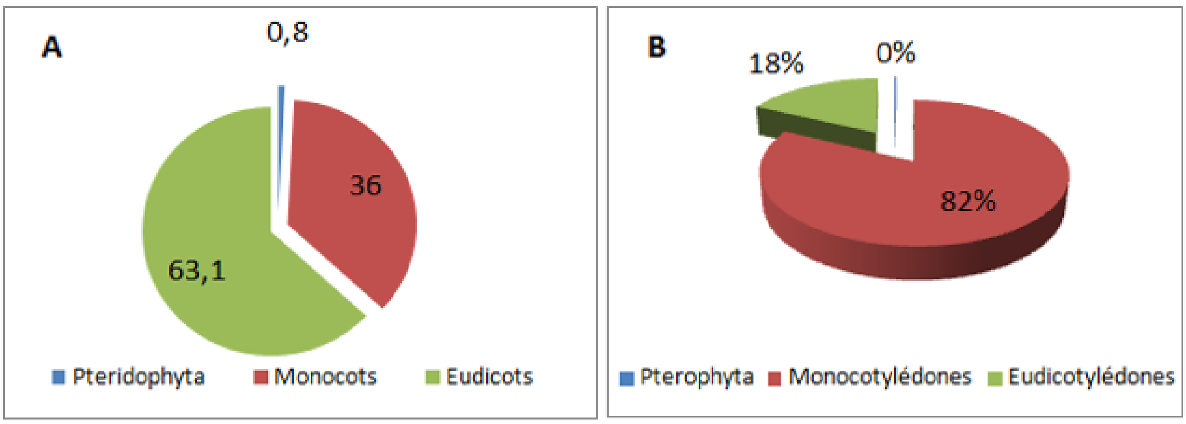


Figure 5: Specific richness spectrum of the three clades (A) and their mean densities (B)

The two diagrams present different patterns: Pterophyta remains insignificant in both; monocots show higher density in the second diagram compared to their specific richness in the first. Semi-aquatic environments generally repel pteridophytes compared to the uplands of Kisangani, where Lubini (1982) and Germain (1947) recorded far more species, working in larger areas.

Ecological group analysis

The presence of a given plant provides information about the place where it grows. The plant in question has approximately suitable and assembled conditions that allow it to grow and survive. The adaptations of species within the phytocoenoses made it possible to identify autoecological characteristics, presented here in the form of phytogeographical spectra (Figure 6), biological spectra (Figure 7), phytosociological group spectra (Figure 8), and diaspore type spectra (Figure 9).

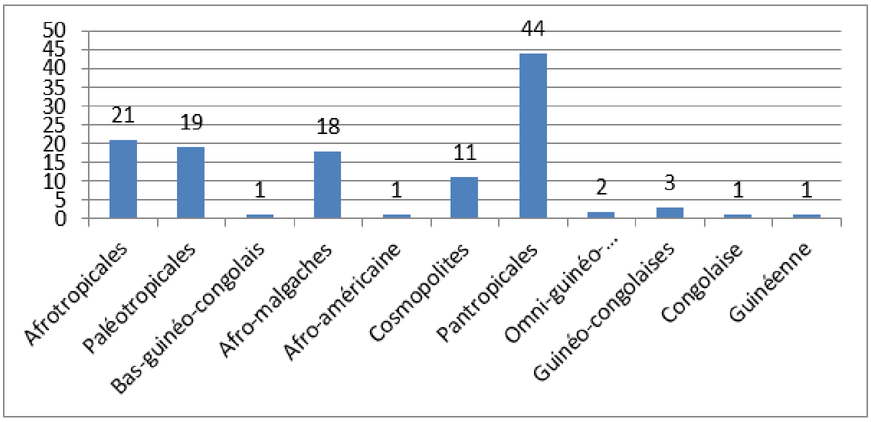


Figure 6: Phytogeographical spectrum of the species of the florule

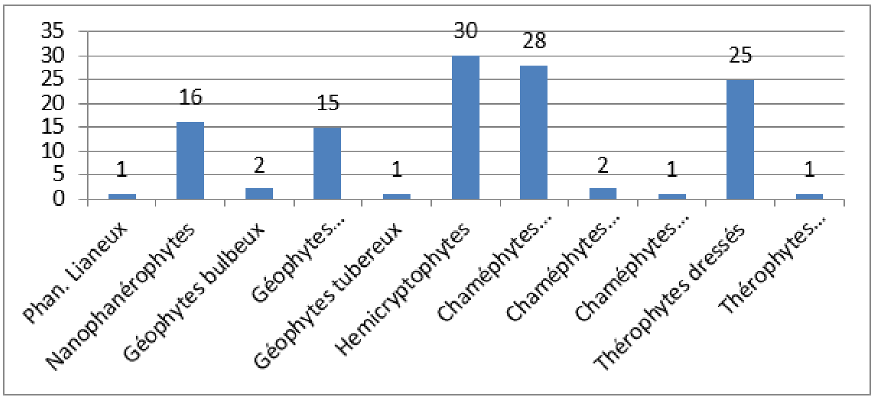


Figure 7: Biological spectrum of the species recorded in the florule

The quantitative analysis of biological types shows the dominance of hemicryptophytes over erect chamaephytes, erect therophytes, nanophanerophytes, and rhizomatous geophytes. Creeping chamaephytes and bulbous geophytes are scarce. Lianescent phanerophytes, tuberous geophytes, climbing chamaephytes, and tufted therophytes are negligible in the florule. The repetition of seasonal crops does not allow phanerophytes, creeping species, and climbing species to adapt and thrive.

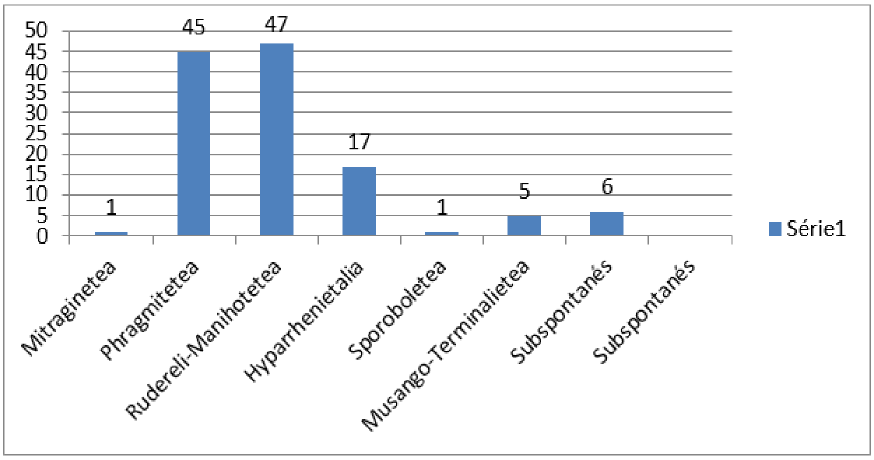


Figure 8: Spectrum of phytosociological groups of the florule

The florule is best represented by species of Ruderali-Manihotetea (47), followed by those of Phragmitetea (45), then Hyparrhenietea. Subspontaneous species are less present. Those of Musango-Terminalietea are far fewer. The representatives of Mitraginetalia and Sporoboletalia are of very low importance. Ruderal species migrate rapidly into drained areas of humid environments.

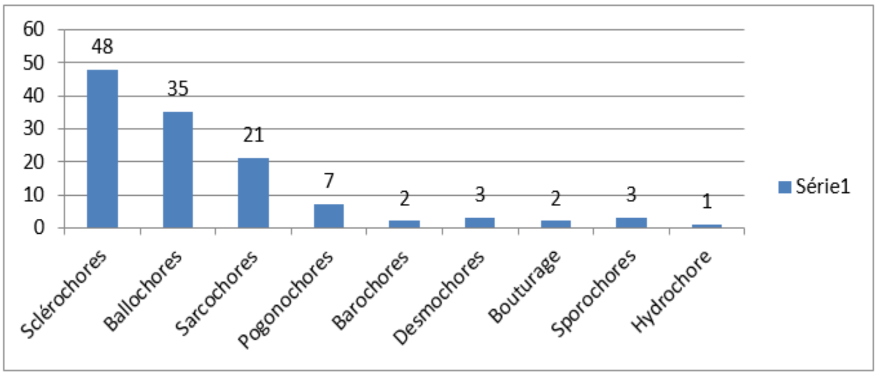


Figure 9: Spectrum of diaspore types of the florule

Sclerochores (48 species) are the types of diaspores that best disperse hydrophilic grasslands of the investigated humid lowland vegetation, compared with ballochores (35 species) and sarcochores (21 species). The other categories of diaspores are of little importance. Anemochory is therefore the most efficient mode of dispersal for the flora in the described wetland area.

Floristic Affinity of the Phytocoenoses

The discrimination of related associations was based on the calculation of floristic community coefficients using Sørensen's formula, which determines the degrees of similarity between different relevés:

$$Is = 2C / (a + b) \times 100,$$

In which is the Sorensen coefficient, c represents the number of species common to the two associations, and (a + b) the total number of species constituting the two associations being compared. The calculation yields the floristic community indices, presented in a table corresponding to a matrix whose rows and columns are assigned to the phytocoenoses compared pairwise, and whose intersections show their indices.

Table 1: Sørensen similarity (%) between pairs of plant communities

	1	2	3	4	5	6	7	8	9	10
1	100									
2	21,2	100								
3	28	16,8	100							
4	27,4	23,3	35	100						
5	36,6	27,1	38,8	42,4	100					
6	38,2	32,8	25	34,4	41,9	100				
7	41,2	32,9	37,1	34,4	47	60	100			
8	35,8	24,6	17,8	32	37	34,7	38,4	100		
9	25,8	10,5	29,1	28,5	30,4	20,4	27,2	20	100	
10	25	20,4	20,4	13,9	21,2	34,1	26,6	25,8	34,7	100

Similarity values above 50% indicate homogeneity, observed between communities 6 and 7, with a Sorensen value of 60%.

Characterization of phytocoenoses based on diversity indices

In the florule, the phytocenoses have been identified and characterized: I (*Cyperus distans var. distans,* II (*Polygonum pulchrum*), III (*Triumfetta cordifolia var. cordifolia* et *Cyperus distans var. distans*), V (*Vossia cuspidata*), VI (*Ludwigia abyssinica*), VIII (*Cyperus papyrus percamentus*), IX (*Hyparrhenia subplumosa*), X (*Triumfetta cordifolia var. cordifolia*).

Table 2: Comparison the plant communities using diversity indices

		II	III	IV	V	VI	VII	VIII	IX	X
I		0,032	0,321	0,481	0,816	0,467	0,346	0,019	0,248	0,038
II	1		0,326	0,092	0,021	0,337	0,271	0,822	0,103	0,924
II	1	1		0,704	0,266	0,694	0,957	0,227	0,924	0,436
IV	1	1	1		0,547	0,949	0,666	0,067	0,640	0,139
V	1	0,982	1	1		0,557	0,479	0,031	0,252	0,031
VI	1	1	1	1	1		0,886	0,296	0,674	0,356
VII	1	1	1	1	1	1		0,123	0,836	0,235
VIII	0,892	1	1	1	1	1	1		0,067	0,751
IX	1	1	1	1	1	1	1	1		0,168
X	1	1	1	1	1	1	1	1	1	

The diversity indices valued I and II, I and VIII, I and X, II and IV, II and V, IV and VIII, V and VIII, V and X are very low, close to 0.

DISCUSSION

Ecological Condition

The colonization of the studied wet lowlands is optimal for hemicryptophytes, as the environment is more favorable to them than to other life forms. These species show uniform distribution and overshadow less competitive species, hindering their growth. Murray (2009) reports that competition for light, nutrients, and water adds to allelopathy caused by toxic secretions that inhibit germination of neighboring seeds.

The studied wetland environment is unfavorable to pteridophytes, which cannot withstand repeated anthropogenic disturbances in areas used for market gardening during the dry season. Seasonal cultivation prevents phanerophytes, creeping, and climbing species from adapting and thriving.

Species Richness

Poaceae contain more species (24) than other families. Eudicots are richer (77 species) than monocots (44) and pteridophytes (1). However, monocots are denser (82%) than eudicots.

Pterophyta is poorly represented, while monocots appear denser than their species richness would suggest. In Aru, semi-aquatic environments are less favorable to pteridophytes due to prolonged dry seasons (4 to 6 months), contrary to Kisangani uplands where Lubini (1982) and Germain (1947) worked on larger areas.

Phytogeographical Distribution

Pantropical dryland species predominate in the wet phytocoenosis. According to Devineau (1998), a high proportion of widespread species may indicate degradation: the flora loses specificity, and the degree of "pollution" can be assessed by the presence of ubiquitous types expressing anthropogenic pressure.

The floras analyzed in the Aru watershed are polluted by invasive species of the class Rudereli-Manihotetea.

Species Dispersal

Plants with small, light diaspores (sclerochores and sporochores), easily carried by wind, are best represented in Aru savannas, even in hydromorphic soils where herbaceous plants are abundant. This result agrees with Coiffait-Combault (2011) on Mediterranean herbaceous communities and Ali (2006) on the vegetation of Niger's W National Park.

Vegetation Dynamics

The vegetation studied shows that, rather than progressing normally toward the local climax represented by riparian forest, it remains at a lower stage. A subclimax dominated by *Cyperus distans* var. *distans*, sometimes *Pennisetum purpureum* or *Cyperus papyrus percamentus*, persists. This climax is adapted to climatic and edaphic modifications.

According to Léonard (1950), it is defined as a permanent plant community whose evolution toward the climatic climax is delayed by factors whose influence is exerted in a more or less lasting manner, such as fire, soil, slope, animals, grazing, or cultivation.

The similarity coefficients revealed floristic homogeneity between communities 6 (*Triumfetta cordifolia* var. *cordifolia* and *Cyperus distans* var. *distans*) and 7 (*Pennisetum purpureum*), whose Sorensen similarity index reached about 60%. These related communities are linked by the nature of the clay–sandy substrate on which they develop. Their species were recorded on more or less well-drained surfaces. Lubini (1982) observed similar affinities in his study on marshland crops.

The diversity index values between communities I and II, I and VIII, I and X, II and IV, II and V, IV and VIII, V and VIII, and V and X are very low, close to 0. These plant assemblages, belonging to different ecological gradients, share no common species. The other pairs, with values between 0 and 1, are relatively similar.

CONCLUSION

This study aimed to analyze, from a phytosociological perspective, the wet lowlands embedded in the valleys of northern Ituri Province in Aru Territory, in order to characterize the composition and ecological structure of their vegetation. These lowlands show large areas dominated by Cyperaceae. The hydromorphic conditions of the environment are highly favorable to *Cyperus distans* var. *distans*, which appears resistant to anthropogenic pressures.

The cladistic, biological, phytogeographical, and phytoecological spectra were highlighted. The transgressive families, particularly Poaceae, are more diversified than Cyperaceae. Hemicryptophytes, sclerophytes, and pantropical species are predominant. Among the ten analyzed vegetation communities, two showed floristic homogeneity, with a Sorensen similarity index of 60%. The others displayed similarity indices below 50%, indicating a lack of floristic homogeneity. Diversity indices were used to compare the floristic diversity of the surveyed wetland vegetation and revealed several common phytocoenoses, while others were not.

Some of the recorded communities had already been reported in the Congo Central Basin by Nyakabwa (1982), notably *Vossia cuspidata* (Vanderist 1931) Lebrun 1947 and *Leersietum hexandrae* nov. (Nyakabwa 1982).

Wetlands constitute an invaluable natural heritage. Many plant and animal species are strictly associated with them. Wetlands contribute to regulating river flow (flood attenuation, flood prevention, and dry-season flow support). Their ability to store and gradually release large quantities of water supports both groundwater and surface water recharge. By promoting purification through their rich biocoenosis, wetlands help preserve water quality.

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